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PRESENT STATUS OF THE HIGH RESOLUTION SPECTROMETERS

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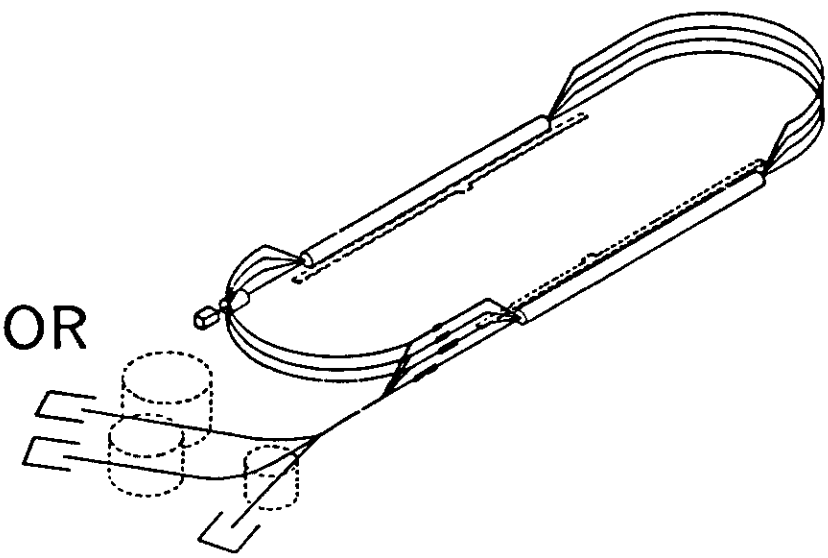

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Present Status of the High Resolution Spectrometers

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1. Introduction

The Hall A spectrometer set up is designed primarily for the part of the CEBAF program which requires energy resolutions comparable to the designed value for the beam energy spread ($4\sigma_E = 10^{-4}$). It deals mainly with completely exclusive experiments in which the nuclear (bound) final state has to be fully specified. Typical values for the required missing mass resolution range from $\sim$ 1 MeV in light systems (d $\longleftrightarrow$ np separation) to $\sim$ 100 KeV in heavy nuclei, or for hypernuclear spectroscopy. High accuracy in the definition of the particle emission angles is also required to achieve the missing mass resolution and to allow absolute determination of cross sections to the level of 1%. Discussions on these points can be found in many contributions to this workshop, as well as in the proceedings of the previous CEBAF Summer Workshops and Summer Study Meetings.

Moreover, following the recommendations of the CEBAF Program Advisory Committee, design modifications are being studied to accommodate extended targets, with more moderate resolution. This would allow to accomplish a significant fraction of the few nucleon studies, including single arm (e,e′) experiments. The need for out-of-plane capabilities in Hall A has been reemphasized, and the best strategy to achieve this goal has to be defined very soon. Modifications required to accommodate polarized hydrogen and deuterium targets have also to be examined.

The major requirements for Hall A spectrometers, derived from kinematics and cross section evaluations of some typical experiments are given in Table I. In addition, the two spectrometer set-up should allow to operate at high luminosity values ($\geq 10^{38}$ cm^{-2} sec $^{-1}$). The hall configuration should make possible the future implement of a third spectrometer, likely to be with $p_{max} \leq 1.5$ GeV/c, larger momentum and angular acceptances and shorter optical length. Such spectrometer could be used to detect kaons, pions, backscattered electrons and/or to perform triple arm experiments. Neutron detection capabilities should also be implemented.

Table I

Major Requirements for Hall A Spectrometers

	Electron Spectrometer	Hadron Spectrometer
Maximum momentum	4 GeV/c, upgradeable to 6 GeV/c	3GeV/c
Momentum acceptance	$\sim 10\%$	$\geq 10\%$
Solid angle	~ 10 msr	≥ 10 msr
Angular range	$\leq 10^o$, 130^o	$\leq 10^o$, 130^o
Angular position accuracy	~ 0.1 mr	~ 0.1 mr
<u>Thin target mode</u>		
Momentum resolution δp/p	$\leq 5.10^{-5}$ optimized at 2 GeV/c	$\leq 10^{-4}$
Angular resolution $\delta\theta = \delta\phi$	~ 1 mr	~ 1 mr
Transverse position resolution δy	~ 0.3 mm	~ 0.3 mm
<u>Extended target mode</u>		
Target length acceptance (at 90^o)	$\sim \pm 5$ cm	$\sim \pm 5$ cm
Momentum resolution	$\leq 3.10^{-4}$	$\leq 3.10^{-4}$
Angular resolution	≤ 1 mr	≤ 1mr
Transverse position resolution	~ 1 mm	≤ 1 mm

2 - Hall A Configuration

The proposed spectrometer arrangement in Hall A is shown in Figure 1. The Hall itself is a circular underground building, 175' inner diameter, clearspan (no column), with 51' total height under crane hook, the beam height being 9' above floor. A 20 ton crane with maximum coverage will be permanently installed, while a mobile one (50 tons) will be used for initial spectrometer assembly and on demand. Truck access to end station floor for heavy loads will be possible through a hoistable platform (50 tons, 60' long). The off-centered location of the spectrometer pivot allow to reduce the room diameter, thus, in particular, the cost of the roof, without significantly hampering the angular motion of the spectrometers. The choice of the spectrometer configuration – one horizontal, one vertical – is discussed thereafter. Both spectrometers can separately reach a 10° forward angle (defined at the center of their acceptance), while the minimum angle between the two will be around 30°.

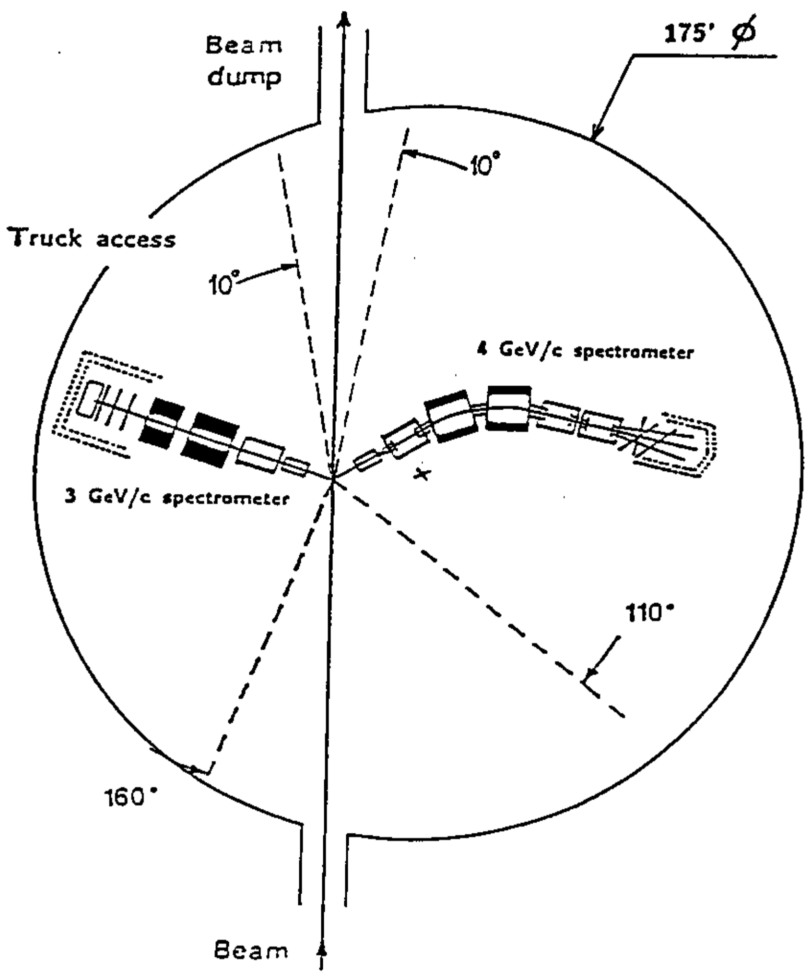


Figure 1 Spectrometer Arrangement in Hall A

As shown in Figure 2, the proposed scenario for out-of-plane measurements is to move the beam in the vertical plane, in one among five channels with angular spacings such as to provide sufficient overlap with the $\pm 5^o$ ($\pm 2^o$) vertical acceptance of the electron (proton) spectrometer. In that scheme, by using discrete channels, one avoids the radiation problems created when bending the beam back to the 0^o dump, due to bremsstrahlung and energy-degraded electrons. Moreover, it makes the system totally free of any mechanical motion. However, as the auxiliary beam dumps are closer to the end station roof, their power rating may have to be limited to $\sim 10\%$ of the main dump one.

At present, the solution of moving the beam rather than lifting one spectrometer – namely the hadron one – is preferred, considering technical difficulties, costs and the high accuracy required for these experiments. I shall come back later on kinematical implications of this scenario.

3. Electron Spectrometer

The basic design for the 4 GeV/c electron spectrometer is shown in Figure 3, as it was defined about a year ago.[1] The main characteristics are listed in Table II. It is a QQDDQQ, essentially symmetric design, with a total bending angle of 45^o, and a first order resolving power of 47000 for a beam spot size of 0.2 mm. Without changing distances between the various elements, it can be reconfigured to a 30^o bending angle, 6 GeV/c spectrometer. With the same optical length, the radial length is increased by 0.8 mm, and the resolving power decreases to 31000. The spectrometer is bending horizontally. This allows to make optimal use of the dipole apertures while having an angular acceptance which is smaller in the plane of scattering, in which the cross section varies rapidly with angle. Its optical properties are shown in Figure 4, through the first order characteristic trajectories. Point-to-point imaging in both planes, to second order, is obtained along a 45^oinclined focal plane by a sextupolar field component built inside the third quadrupole (Q3/M3). In between the two dipoles, the first order conditions $<y|\phi> = <\theta|\theta> = 0$ are realized. The transverse cross-over ensures modest dipole gaps (30 cm) in view of the large $\pm$ 90 mr angular acceptance, while the radial condition $<\theta|\theta> = 0$ makes optimum use of the pole width to build up resolving power. The drawbacks of this attempt to combine high resolution and large acceptances in a short, weakly bending, economical design are a large $<y|y>$ term in the last dipole and quadrupoles, and important higher order couplings

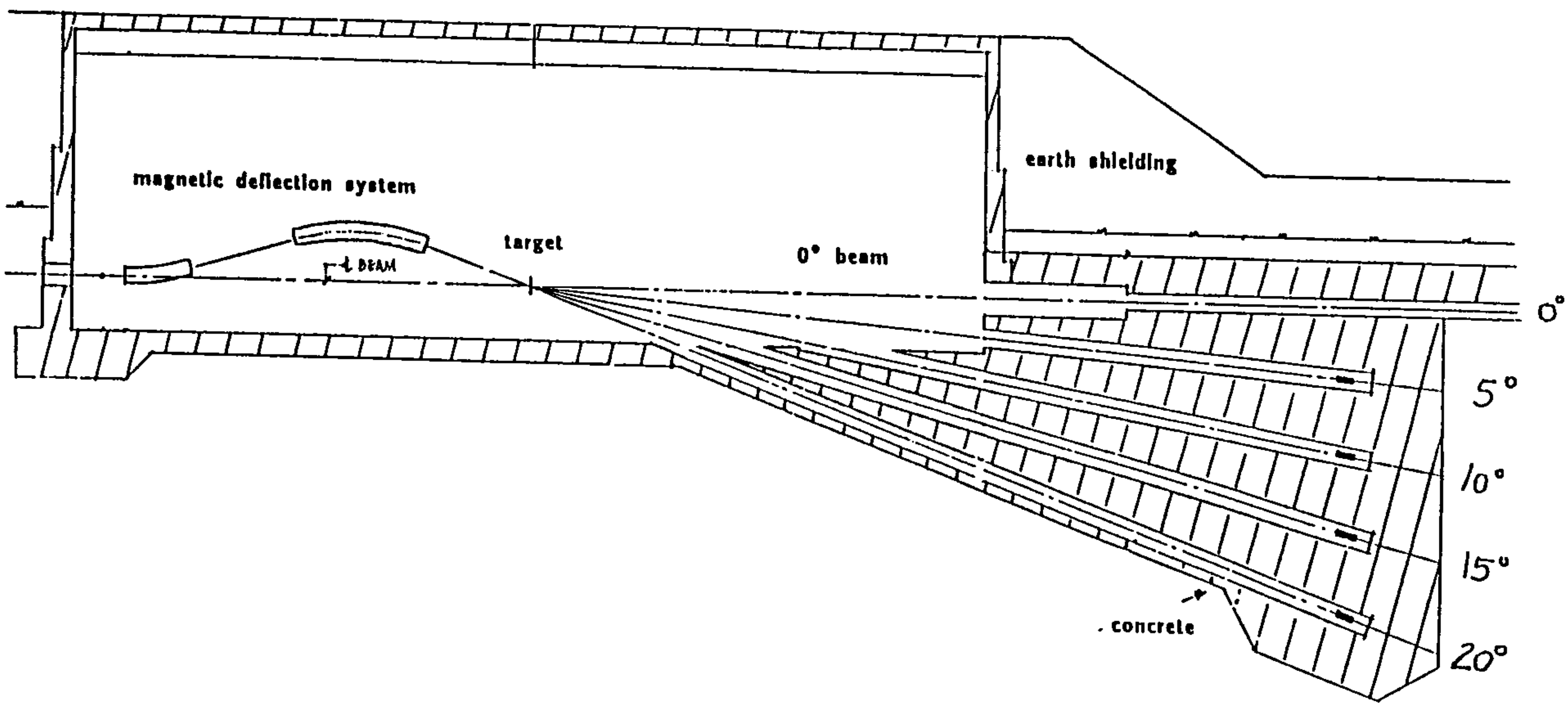


Figure 2 End Station A Out-of-plane set up. Only one of the entrance magnetic systems is represented, for sake of clarity.

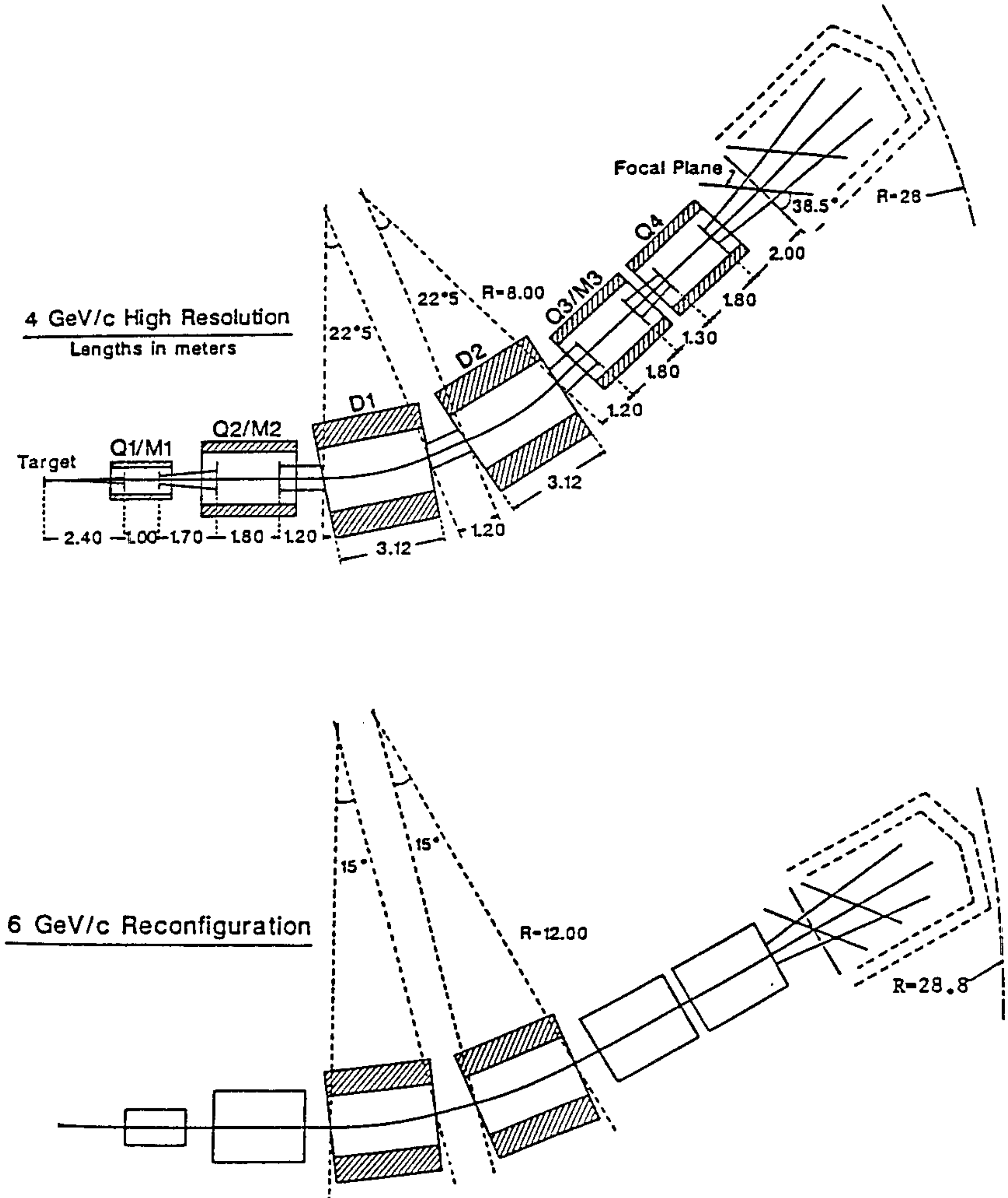


Figure 3 Schematic lay-out of the high resolution electron spectrometer for Hall A.

Main Design Parameters for Hall A Spectrometers

General Parameters	Electron Spectrometer*	Hadron Spectrometer
Type	QQDDQQ	QQDD
Bending	horizontal, 45° (30°)	vertical, 60°
Physical length (m)	23.7	18.0

Optical Parameters	Electron Spectrometer*	Hadron Spectrometer
Maximum momentum	4 GeV/c (6)	3 GeV/c
Momentum acceptance (%)	± 5	± 7.5
Solid angle (msr)	10.8	10.8
Angular acceptance horiz.	± 30	± 75
(mr) vert.	± 90	± 36
Momentum dispersion (cm/%)	9.94	6.97
Transverse focusing	point to point	point to point
Linear magnification horiz.	- 1.064	- 6.380
vert.	0.993	- 1.148

Technical Parameters

Dipoles	Electron D1	Electron D2	Hadron D1	Hadron D2
Magnetic length (m)	3.12	3.12	3.12	3.12
Physical aperture	160 x 30	160 x 30	160 x 30	160 x 40
Bending radius (m)	8	8	6	6
Maximum field	1.67	1.67	1.67	1.67
Bending angle (deg.)	22.5° (15°)	22.5° (15°)	30°	30°
Amp x turns ($\times 10^6$)	0.48	0.48	0.48	0.64
Stored energy (MJ)	2.8	2.8	2.8	4.8

Quadrupoles	Electron Q1	Electron Q2	Electron Q3	Electron Q4	Hadron Q1	Hadron Q2
Magnetic length (m)	1	1.8	1.8	1.8	1	1.8
Warm bore diameter (m)	0.44	0.8	0.8	0.8	0.44	0.8
Inner coil diameter (m)	0.5	1	1	1	0.5	1
Maximum quadrupole strength (T/m)	8. (12.)	2. (3.)	2.1 (3.2)	4.8 (7.2)	6.2 (9.3)	2.3 (3.5)
Designed value	12	7.5	7.5	7.5	12	7.5
Maximum sextupole strength (T/m^2)	0	0.3 ( )	0.3 ( )	0		
Maximum octupole strength (T/m^3)	2.9	0.14 ( )	0 ( )	1.4 ( )		
Quad. amp x turns ($\times 10^6$)	2.4	7.2	7.2	7.2	2.4	7.2
Stored energy (MJ)	1.5	5.3	5.3	5.3	1.5	5.3

*All parameters are for 4 GeV/c maximum momentum. Numbers under parenthesis are the corresponding values for 6 GeV/c, when different between transverse and radial planes generated by the strongly focusing entrance doublet. Such higher order terms will have to be corrected by software.

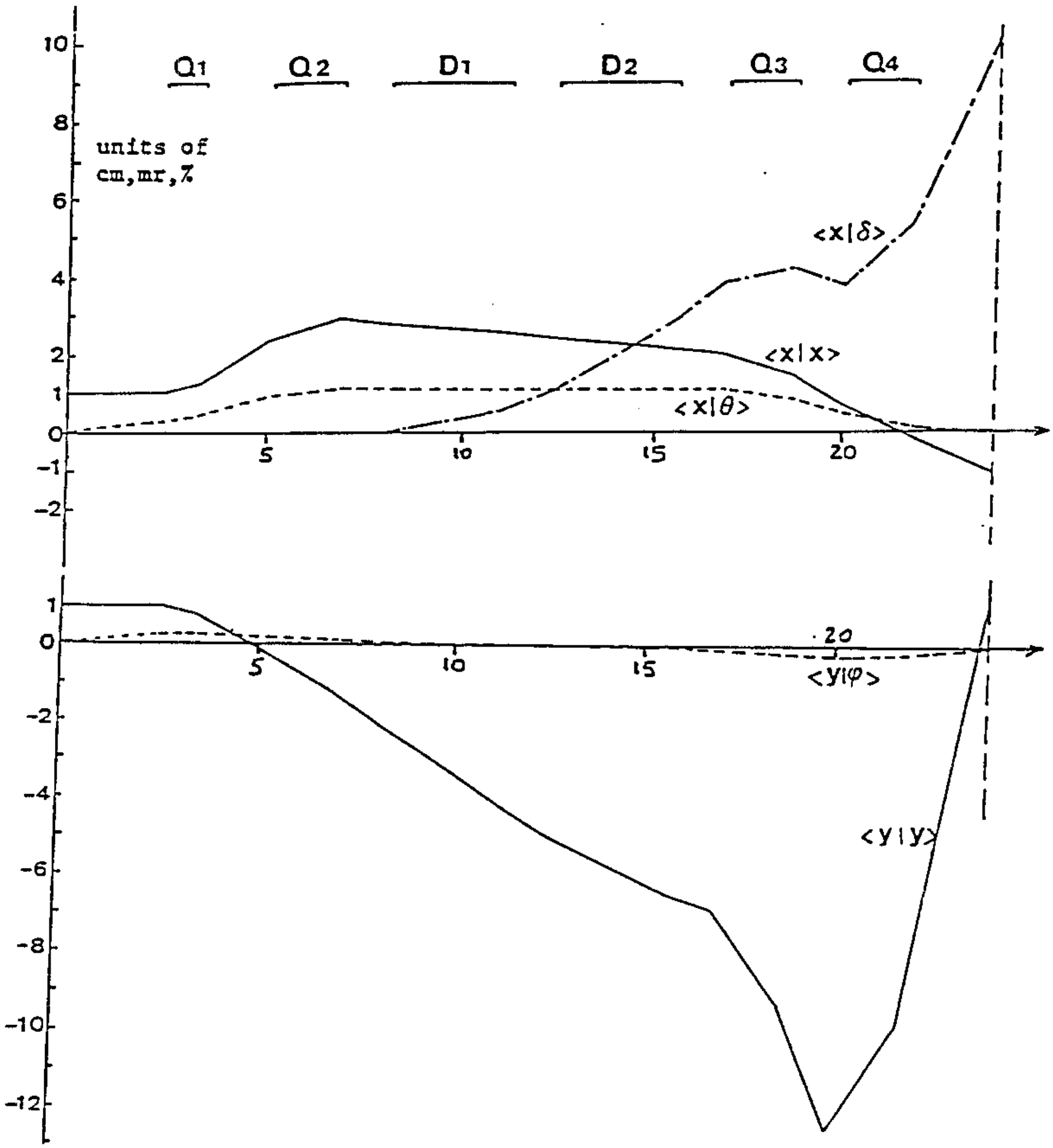


Figure 4 Characteristic ion-optical trajectories (first order) through the 4 GeV/c electron spectrometer.

The optical properties have been studied in the thin target mode of operation using raytracing (RAYTRACE, SNAKE) and multidimensional fitting (MUDIFI) computer codes. Prior to the software backtracing of the trajectories, the design has been optimized through third order by including sextupolar and octupolar fields in the quadrupole elements. Models were used to define dipole and quadrupole fringe fields, as the geometry of the magnetic elements is not yet fully finalized. Using a beam spot size of $\delta x_o = \pm 0.1$ mm, $\delta y_o = \pm 0.1$ mm, and the full spectrometer acceptances, $\Delta p/p = \pm 5\%$, $\Delta\theta = \pm 30$ mr, $\Delta\phi = \pm 85$ mr, 2000 trajectories have been selected randomly, traced through the spectrometer and used to define a set of coefficients allowing to trace back θ_o, y_o, ϕ_o and the relative momentum deviation δ_o at the target location. Using another set of 2000 random trajectories, the resolution of the spectrometer was obtained by comparing the true and traced back intital trajectory coordinates. For that purpose, finite detector resolutions were introduced by modifying randomly the final trajectory coordinates within the following limits:

$$\delta x = \delta y = \pm 0.1 \text{ mm} \qquad \delta\theta = \delta\phi = \pm 0.5 \text{ mr}$$

With such procedure, the following figures for the resolutions (FWHM) are obtained (see also Figure 5).

$$\delta p/p = 2.5\ 10^{-2} \qquad \delta y = 0.44 \text{ mm}$$

$$\delta\theta = 1 \text{ mr} \qquad \delta\phi = 0.9 \text{ mr}$$

As already explained, the spectrometer is planned to be built out of a few "modular" elements: Q2, Q3, Q4 are identical cos 2θ quadrupoles, with superconducting coils and warm iron yokes. An appropriate coil geometry (3 sectors) allows to eliminate the dominant higher order multipoles, and to make optimal use of the aperture. The front quadrupole Q1 has half inner coil diameter and a cold bore at liquid N_2 temperature, to allow small angles with the beam. Additional layers of conductors, powered independently, can be used to produce sextupole or higher order multipole fields which can be tuned either to correct spectrometer aberrations, or to compensate for unwanted high order multipole contributions coming from fringe fields, misalignments,...

4. Hadron Spectrometer

A layout of the design for the 3 GeV/c hadron spectrometer which was considered at the time of the Workshop is shown in Figure 6. It consists in a QQDD, 60°

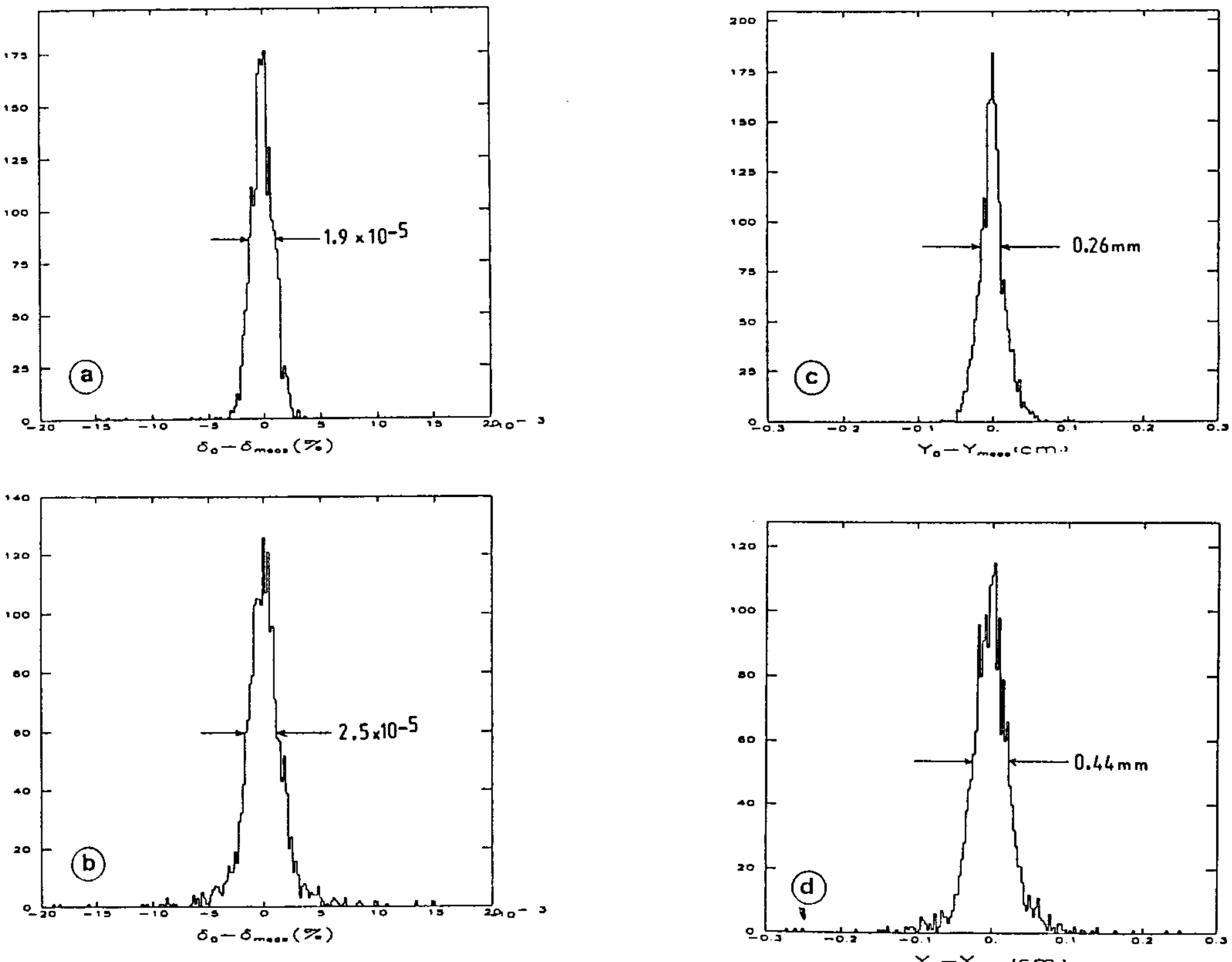


Figure 5 Computed momentum (a and b) and transverse position (c and d) resolutions in the 4 GeV/c spectrometer, without (a and c) and with (b and d) finite detector resolution (see text).

bend, 18m long vertical spectrometer, which makes use of the same basic modules as the electron spectrometer. Its main characteristics are given in Table II. The first order optics is shown in Figure 7, in terms of the usual characteristic trajectories. Here the spectrometer is tuned to be point-to-point focusing in the transverse plane. The large $<y|y>$ term allows very precise reconstruction of the reaction point, even at small forward angles. This data is needed for trajectory reconstruction in the electron spectrometer when coincidence experiments are performed on extended targets. The counterpart is small target length acceptance ($\sim \pm 2$ cm) unless one increases the dipole gaps substantially. Moreover, the $< \phi|\phi >$ term is small ($= 1/<y|y>$), resulting in a rather poor angular resolution of $\sim$ 3 mr in the horizontal plane.

The resolving power for a 0.2 mm beam spot size is 30000. The small $<x|x>$ and $<x|\theta >$ terms in the last dipole allow for a resonably large momentum acceptance of $\pm$ 7.5%. However, the use of "standard" dipoles makes that all the focusing occurs in the front doublet. Together with the small bending angle and the short distance from last dipole to focal point, it leads to serious difficulties when trying to bring the focal plane to a reasonable angle, as well as to correct from aberrations. One possibility is to insert a sextupole element – with conventional coils – between the two dipoles.

5. Use of Extended Targets

Experiments on few nucleon systems call for liquid or high pressure gas targets extending along the beam over 10 cm or more. Compared to the $\sim$1 mm source dimension one expects from thin solid targets, it represents two orders of magnitude increase in the required spectrometer acceptance, if one wants to keep the same solid angle value. Moreover, if one realizes that the present designs involve already magnetic elements with very large apertures relative to their lengths, and object and image distances very small compared to the bending radii, one foresees that modifying the designs to accommodate longer targets will not be an easy task.

For single arm experiments – like the measurement of few nucleon form factors – using the electron spectrometer, an additional position measurement in the dispersive plane, somewhere inside the spectrometer, is needed to determine the target reaction point along the beam. As it has to be inside the dispersive part of the spectrometer, the most natural location is in between the two dipoles (Figure 8a). In the standard optics tuning, trajectories are parallel to the spectrometer axis, so

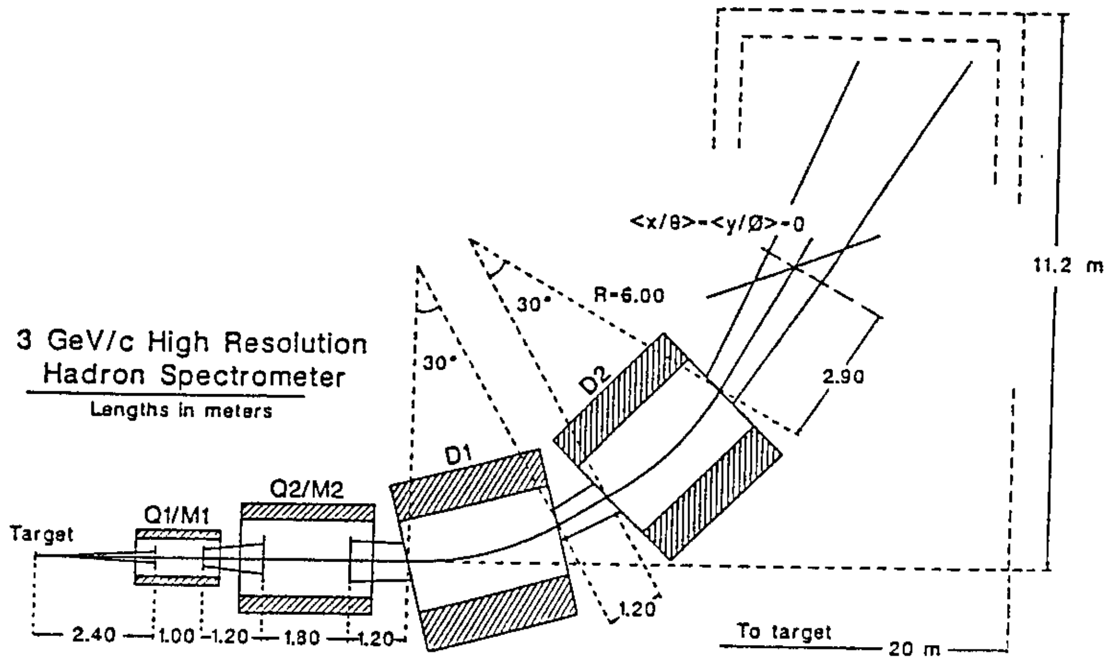


Figure 6 Schematic lay-out of the high resolution hadron spectrometer for Hall A.

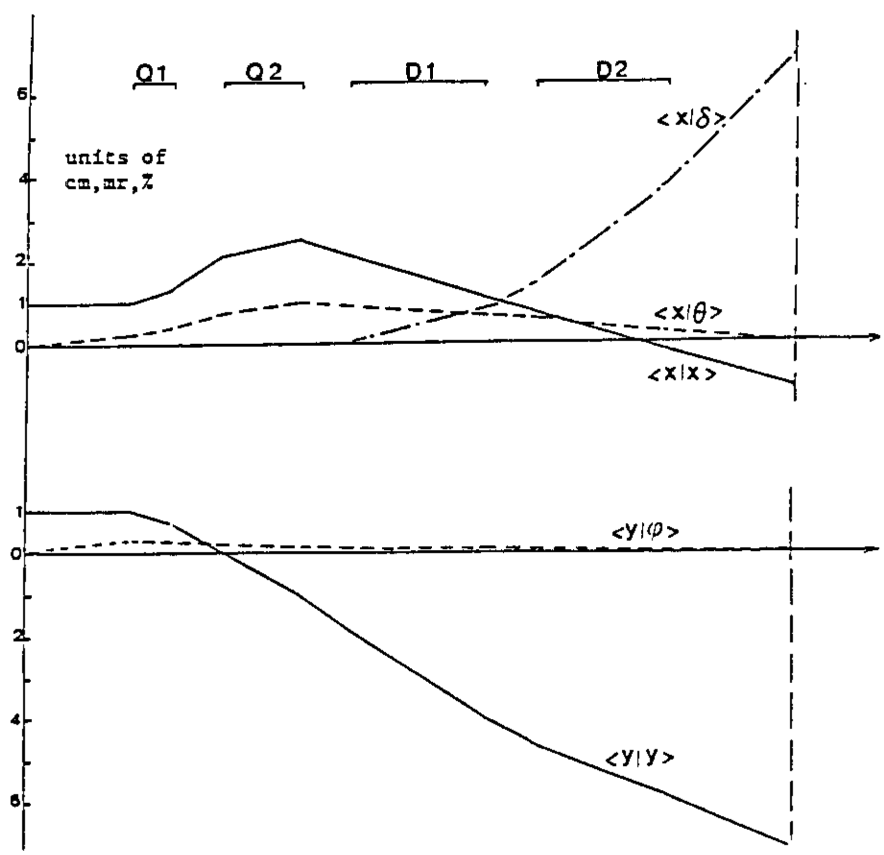


Figure 7 Characteristic ion-optical trajectories (first order) through the 3 GeV/c hadron spectrometer.

multiple scattering effects are maximized. Nevertheless, with a 20 mg/cm^2 detector thickness, their contribution to the resolution is 0.5 MeV (roughly independent of energy) which is still acceptable. However, due to the point-to-parallel first order transformation at this point, the position on target x_o is very badly determined by a position measurement x_1. This completely destroys the resolution. An angular measurement is needed, which can be done by adding a second detector, for instance after the second dipole (Figure 8b). To first order, one has:

$$\delta = 0.4\, x_f + 1.18\, (x_1 - x_2)$$
$$x_o = 2.82\, x_f + 11.0\, (x_1 - x_2)$$

which give x_o and δ with 3 mm and 3.4 10^{-4} resolution respectively. Multiple scattering effects in the first detector are eliminated by the second position measurement, but have dominant contributions to the resolutions (δx_o = 13 mm, $\delta p/p$ = 8.10^{-4} at 2 GeV/c) in the second one. Unless the second detector can be made much thinner than 20 mg/cm^2, the resolution will be about 2 MeV. Another possibility is to tune the spectrometer in a re-imaging mode (Figure 8c) by producing an intermediate focus in the dispersive plane. Due to the symmetric design, the whole spectrometer becomes achromatic. The target position and the momentum are determined using:

$$x_f = \langle x_f | x_o \rangle\, x_o \qquad = 1.07 x_o$$
$$x_1 = \langle x_1 | x_o \rangle\, x_o + \langle x_1 | \delta \rangle\, \delta \qquad = -0.47 x_o - 0.875$$

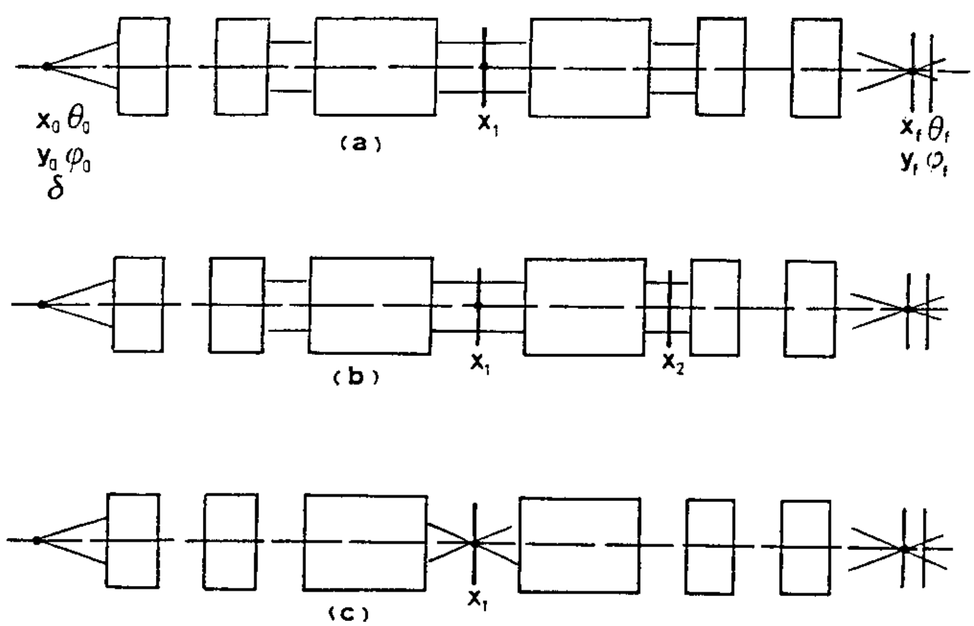


Figure 8 Possible schemes for operating the horizontal electron spectrometer with targets extending along the beam (see text).

With 0.2 mm position resolution, one can achieve $\delta p/p = 2.10^{-4}$ i.e. $\sim$ 1MeV at 4 GeV. Multiple scattering do not contribute to first order, and a target length of $\sim$ 15 cm can be accepted. The increase in field gradient values in the quadrupoles, needed to obtain the intermediate focus, is manageable. However the intermediate "focal plane" is laying at a very small angle (4.5°) with no possibilities to rotate it, due to the very small available distance between the dipoles. This gives rise to large aberrations in both the radial and transverse plane, which, even if they could be corrected by software, would hamper seriously the acceptancies, and increase the detector sizes.

For coincidence experiments, one can use the hadron spectrometer (bending vertically) to determine the reaction point along the beam. At very forward angle, $\theta_p = 10^o$, one can still achieve 1.2 10^{-4} resolution in the electron arm when $\theta_e = 90^o$, which in most cases will correspond to a scattered electron momentum below 2 GeV/c.

However, the present design for the hadron spectrometer suffers from a small target length acceptance due to the large <y|y> term at the end. Modified designs have been considered during the 1987 Summer Study Meeting. Although more work is needed before drawing definite conclusions, a more promising solution is a QDDQ design in which focusing strength in the radial plane is provided by tilted pole faces in the dipoles. By adding a third, weakly focusing, conventional coils quadrupole in front, one can decrease the <y|y> term down to about 3 in the last dipole, which would allow close to $\pm$ 5 cm long targets without increasing the dipole gaps, and with only a slight reduction ($\sim$ 8 msr) in solid angle. The same addition to the electron spectrometer improves its optics also, by decreasing both the <x|x> and <y|y> terms by nearly a factor of 2, at the expense of an increase in length of about 1.5m.

6. Out-of-Plane Experiments

Coincidence measurements under non coplanar kinematics are needed to isolate some of the interference structure functions which enter in the general expression of the coincidence cross sections. As mentioned earlier, an analysis of required accuracies, technical difficulties and costs favors moving the beam rather than a spectrometer. One examines here some implications of the proposed scheme.

Figure 9 shows the kinematics for a (e,e′X) reaction. The beam makes an angle α relative to the (horizontal) plane in which both spectrometers move; ϕ is the angle between the scattering plane (scattering angle θ) and the particle X emission plane; γ is the angle between X and the momentum transfer $\vec{q}$. One has

$$tan\gamma = \frac{e.sin\alpha.sin\theta}{q\sqrt{cos^2\alpha - cos^2\theta}.sin\phi + sin\alpha(ecos\theta - e')cos\phi}$$

Moreover, one has

$$cos\theta = cos\theta_e cos\alpha$$

where θ_e is the (horizontal) electron spectrometer angle.

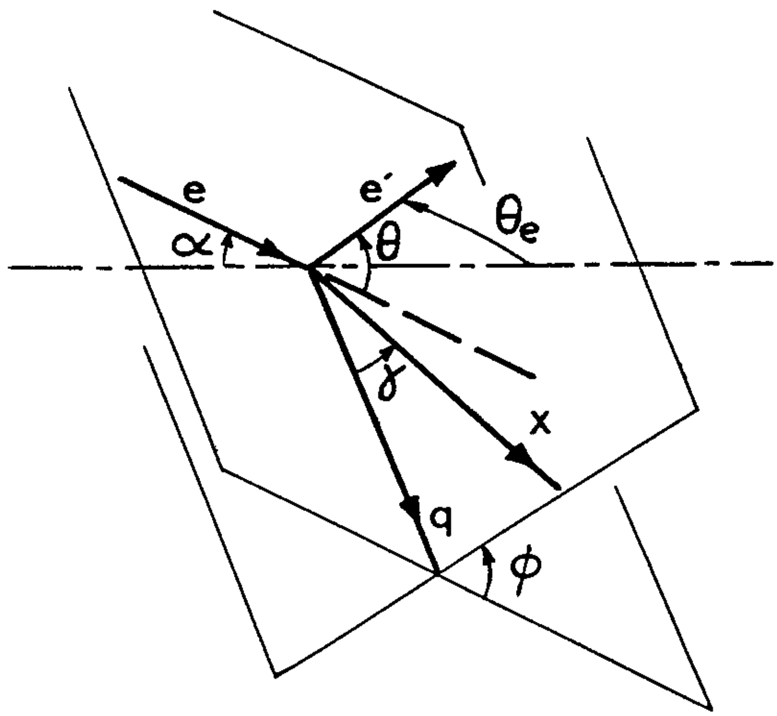


Figure 9 Noncoplanar (e,e′X) kinematics.

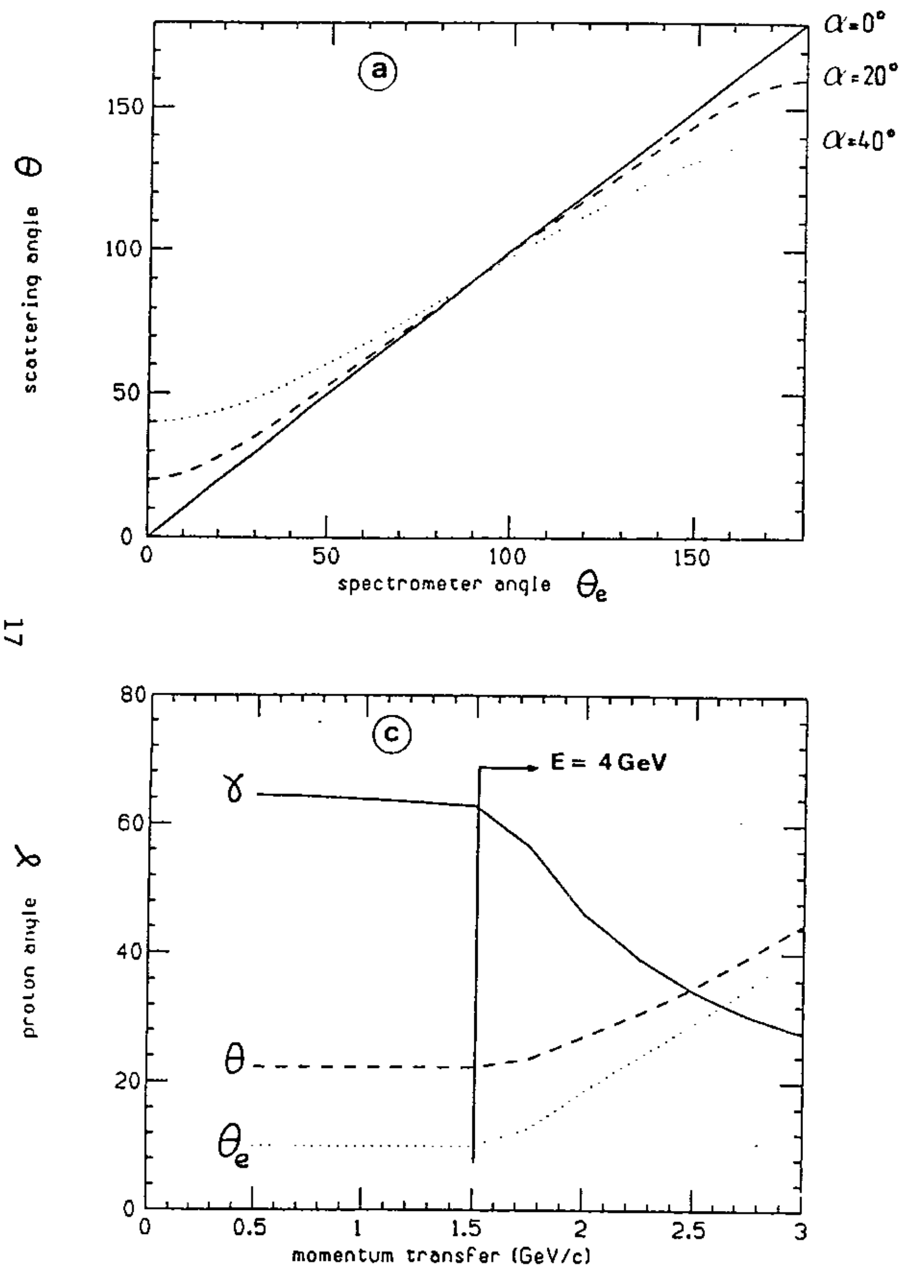
Figure 10a shows θ as a function of θ_e for discrete value of α. One sees that, for $\alpha = 20^o$, the minimum scattering angle is 20^o for θ_e=0, or 22.27^o for $\theta_e = 10^o$, which is an obvious limitation of this scenario. Figure 10b shows the values of γ one can reach for $\phi = 90^o$, $\theta = 22.27^o$, e = 2.56 GeV and q = 1 GeV/c under quasielastic kinematics (x = 1). One has roughly $\gamma = (2.5 \div 3)\phi$. For $\phi \neq 90^o$, γ is larger for the same α value. Under other kinematics with x $\neq$ 0, $\delta\gamma/\delta\phi$ is always much larger than unity. Therefore, the limitation to $\alpha = 20^o$ looks reasonable in this scenario. A practical limit in any attempt to move the hadron spectrometer is likely to be $\gamma = 30^o$. It is clear that experiments for which values of γ larger than 60^o are needed cannot be performed by moving either the beam or any of the large Hall A spectrometers. On Figure 10c, q is varied while keeping $\phi = 90^o$, $\alpha = 20^o$ and the quasi-elastic kinematics condition. The maximum value of γ one can achieve is given at low q by the minimum electron angle $\theta_e = 10^o$, and at high q by the maximum incident energy e = 4 GeV. One sees that, as long as the limitation does not come from the beam energy, γ_{max} is almost independent of q.

7. Use of Polarized Targets

An important fraction of the few nucleon physics program deals with polarization experiments, in particular the use of polarized proton, deuterium and helium targets. Most often, these targets require the presence of a magnetic field in the target volume during the measurement time. The possibility of using such targets together with a pair of focusing, limited acceptance high resolution spectrometer has been investigated. Two kinds of targets were considered.

a. Gas jet targets

An example is the ^{3}He target[2] which is planned to be used for G_E^n measurement through $^3\vec{\mathrm{He}}(\vec{e},e')$ inclusive measurements at the quasi elastic peak. The method used to polarize ^{3}He nuclei is a direct optical pumping technique of a 1 torr cell of ^{3}He gas by an infrared laser beam. It has been demonstrated that a high polarization rate of 70% can be achieved, with a sample thickness of 10^{19} atoms/cm^2. As the beam intensity has to be limited to a few $10^{14}e^-$/sec to control the depolarization rate, the luminosity values are not larger than a few 10^{33} cm^{-2}sec^{-1}. These figures are too low for Hall A spectrometers, and the LAS will be a preferred set up for such measurements.



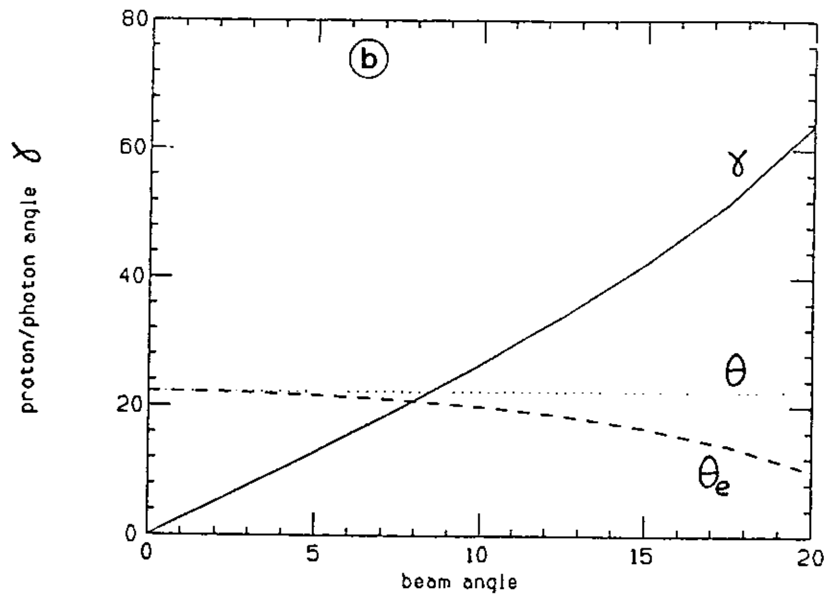


Figure 10 Angular relations and ranges for non-coplanar (e,e′X) kinematics: a) electron scattering angle θ_e; b) proton/photon angle & as a function of the beam angle α off the horizontal plane; c) maximum proton/photon angle as a function of the momentum transfer q. [A quasi-elastic kinematics is considered for b) and c) (see text).]

b. <u>Solid targets</u>

A major breakthrough for the possibility of using polarized solid state targets on external beams has been the development of very low temperature NH_3 and ND_3 targets[3], which have enhanced resistance to radiation damage and high polarization percentages. The dynamical polarization process requires very high magnetic fields (2.5 - 5T) to be applied continuously. To get the required homogeneity of $\sim 10^{-4}$ over a few cm^3 volume in a possible scheme for CEBAF[4], integrated field values $\int \vec{B}.d\vec{l}$ of up to 1 Tm may be experienced by the incoming and outgoing particles. This means $\sim 18^o$ deflection angles for $\sim$ 1 GeV/c particles. This, together with a few cm lateral displacement, is almost incompatible with in-plane, relatively small solid angle spectrometers. However, there are a few cases for which such targets may be envisaged in Hall A[5]. One is the measurement of G_E^n through coincidence (e,e'n) studies with a longitudinally polarized electron beam and a polarized deuteron target. In this case, the target is oriented in the scattering plane, perpendicular to the momentum transfer $\vec{q}$, i.e. at small angle relative to both the incident and scattered electrons. Particle trajectory simulations using the raytracing code SNAKE show that the experiment can be performed in the momentum transfer range $0.5 < Q^2 < 2$ $(GeV/c)^2$, using the 4 GeV/c electron spectrometer. The reduction in solid angle is never higher than 30%, as shown in Table III (preliminary).

Table III

Solid Angle Variation for a $\vec{d}(\vec{e}, e'n)p$ experiment using the 4 GeV/c Electron Spectrometer

Momentum transfer Q^2 $(GeV/c)^2$	0.45	0.95	1.54	2.02
Beam Energy (GeV)	4.	4.	4.	4.
Scattering angle	10^o	15^o	20^o	24^o
Polarization angle				
- re. beam	24.7^o	34.7^o	42.8^o	48.2^o
- re. scattered electron	14.7^o	19.7^o	22.8^o	24.2^o
Fractional solid angle	0.92	0.87	0.80	0.73

8. Magnet Design Studies

As mentioned earlier, the present designs for the spectrometers rely on combinations of a few modular elements. This has been considered simplify magnet studies, permit interchangeability and optimize costs and schedule.

Iron-dominated dipoles with essentially rectangular pole faces, uniform fields ($B_{max} \leq 1.7T$) have been chosen as dispersive elements. The field is expected to be homogeneous to one part in 10^4 within a 100 cm (width) x 30 cm (gap) x 312 cm (length) volume. Superconducting coils have been considered to be efficient[6] in reducing weights and costs, although the use of conventional water-cooled copper coils is not completely ruled out. Several geometries are being studied (see Figure 11). The window frame design allows to reduce the physical aperture, thus the total iron volume. But it implies "saddle-shaped" coils, difficult to realize when superconducting. Lateral forces on the coils which are closer to the high field region are very large. Moreover, as space is needed for cryostat and thermal shields, the coils are far from filling the gap height, which, in turn, makes that one loses the advantage of a high field homeogeneity in such solution. Solutions with separated poles, with tapered filtering gaps and anti-saturating profiles are also studied, either with racetrack coils (11b) or saddle-shaped coils (11c). Although the coil shape is more complicated in the last scheme, the possibility for the coil to be even higher than the gap leads to the best results in terms of field homogeneity and field map stability as a function of the nominal field (which is intended to vary between 0.17 and 1.7T). Detailed field and force calculations as well as an optimization of the end geometries are in progress.

The quadrupole elements have been chosen to be current-dominated, cos 2θ-type superconducting magnets, as large apertures and high field gradients are necessary to accomodate the large acceptances and the high particle momenta. Fields at coil positions reach $\sim$ 4T. A field gradient homogeneity of $\sim 10^{-3}$ is required within $\sim 3/4$ of the inner coil diameter. Each "pole" is defined by three coils winded on the same cylinder, with widths and spacing adjusted so as to cancel higher order multipoles (see Figure 12a). The windings are surrounded by an iron shield, located outside the cryostat. Two kinds of dimensions will be used, the front quadrupole being smaller to allow small forward angles. As the ratio between the effective magnetic length and the coil diameter is very small (1.8 for the large quadrupole, 2 for the small one), 3-dimensional studies are necessary. They are performed using both iron-free codes and the non-linear 3D program TOSCA allowing to study the

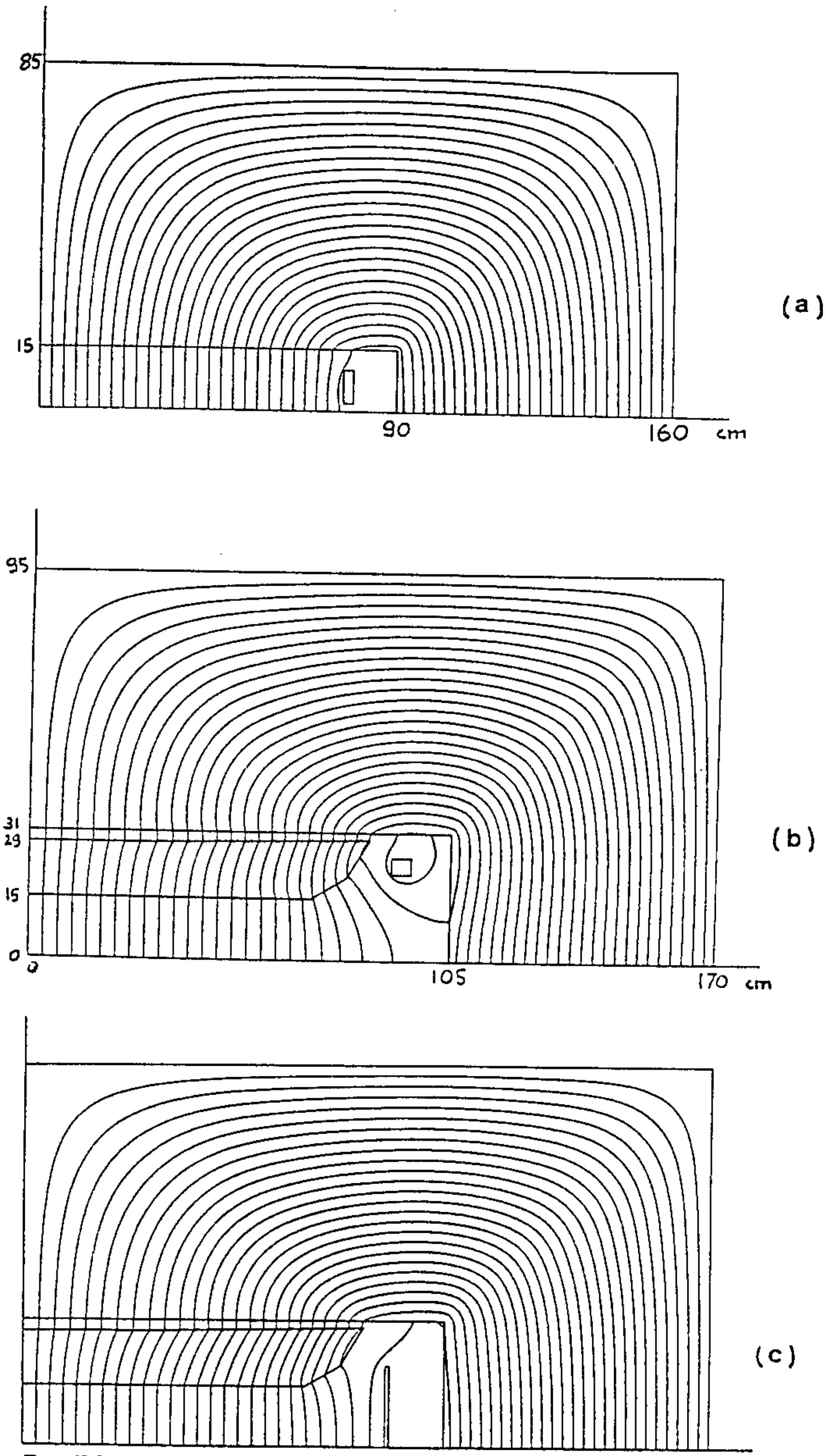


Figure 11 Possible configurations for the superconducting dipole elements. (a) window frame with saddle coils; (b) H-type frame with racetrack coils; (c) H-type frame with saddle coils.

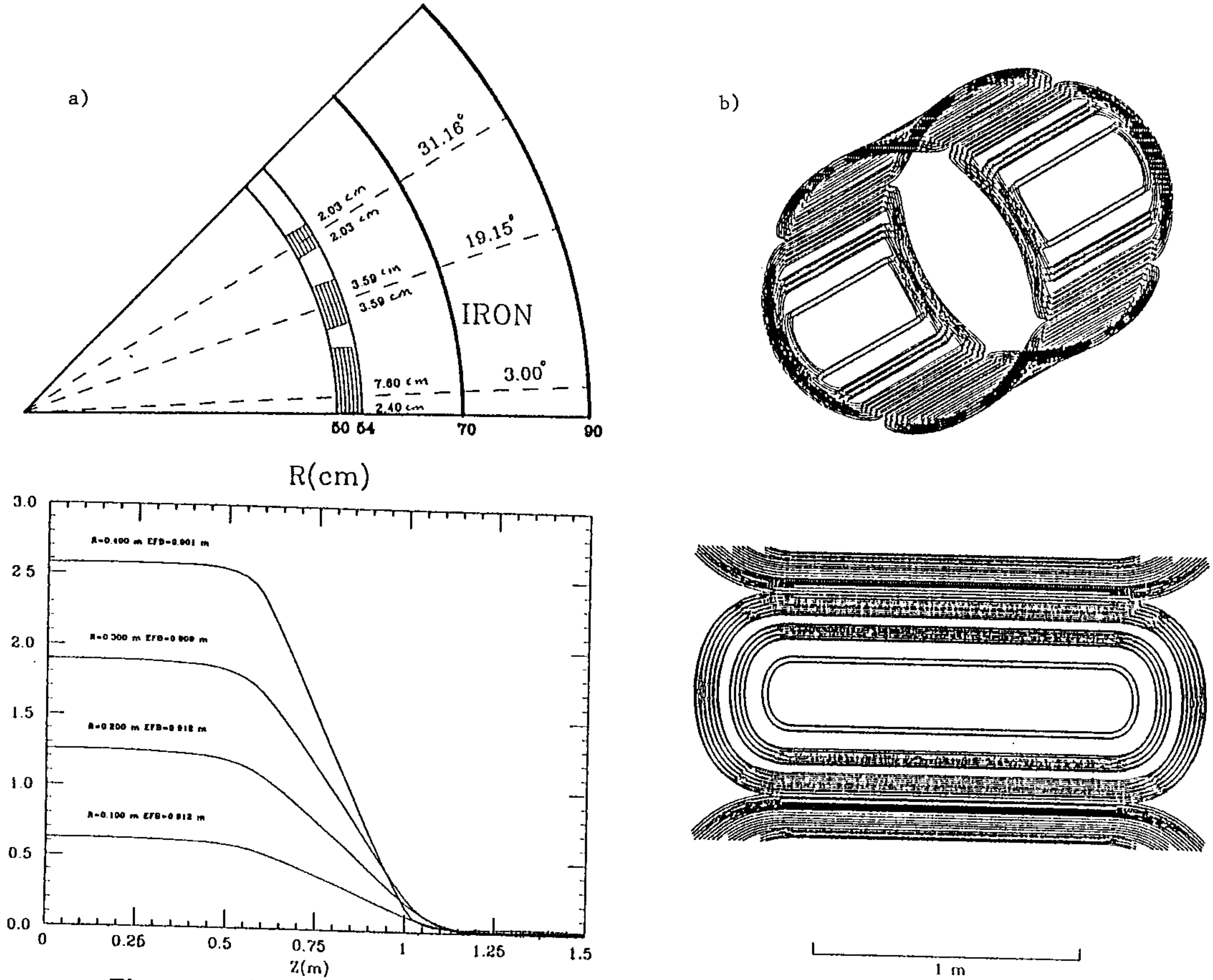


Figure 12 Superconducting cos 2θ quadrupoles (a) coil and iron configuration (b) possible solution for the end coil geometry and corresponding field distribution in the y=0 symmetry plane at various distances from the quadrupole axis.

geometry of the iron shield. Special attention is given to the shape of the coil ends. Standard "constant perimeter" ends tend to exaggerate the already poor aspect ratio. A modified version of them is shown in Figure 12b.

9. Conclusion

Although much work is still to be done, both on spectrometer optics and in design optimization of the magnetic elements, the high resolution spectrometers are gradually taking shape. The optics designs are going to be frozen by the end of September, and the main concepts for the design of the magnetic elements should be defined by the end of the year. A few key questions have to be answered soon, some being extensively discussed during the 1987 Summer Study Meeting. They include:

- Choice of the best scenario for out-of-plane experiments. The physics requirements for each experimental program have to be clearly defined, as well as the needed kinematical ranges and accuracies.
- Extended target capability. Define realistic requirements and tolerances, as well as possible compromises.
- Use of polarized targets: what can – has to – be done in Hall A?

As emphasized also in Costas Papanicolas' contribution, this is certainly an appropriate time for the potential uses of Hall A to express their own views regarding the designs of their future experimental set up. Many opportunities are offered to user collaborations to make actual contributions to the project, in particular (but without limitation) in detection systems, targets and target chambers, aperture defining slits,... which can be defined as fairly independent tasks.

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